Project 3: Amplifier

ELECENG 2EI4

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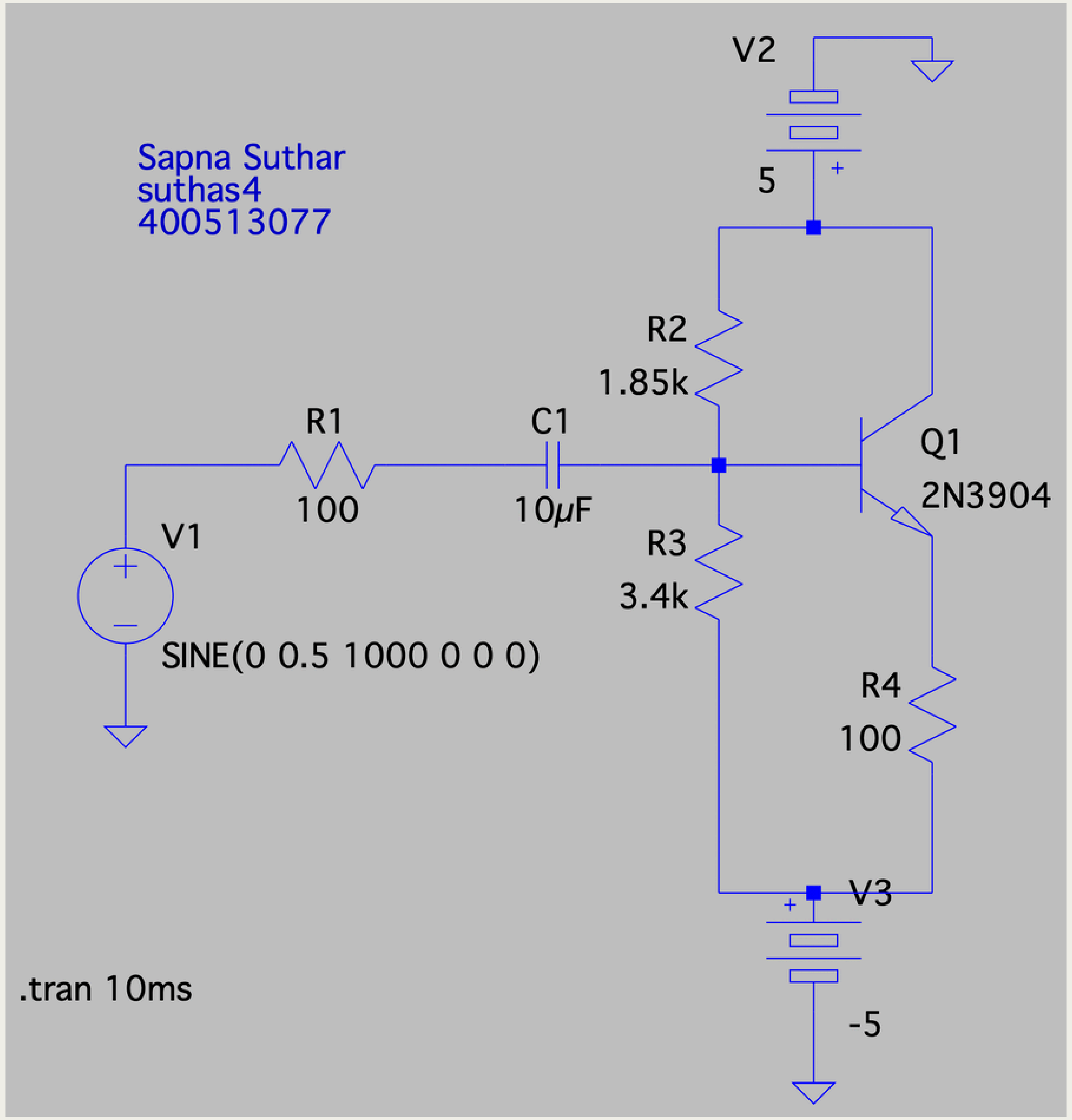
2. CIRCUIT SCHEMATIC



Transistor Type: BJT

- They are commonly used for analog signal amplification
- Performs better in low current applications
- Has a higher gain
- Amplifier state is more linear
  - Gain is independent of bias voltage

Amplifier Topology: Common Collector

- Gain is approximately 1
  - Unity Gain
- Caters best to a larger input signal swing

CALCULATIONS

Minimum Required g_m

$$A_v = \frac{g_m R_L}{1 + g_m R_L} \cdot \frac{R_{in}}{R_t + R_{in}}$$

$$\frac{g_m R_L}{1 + g_m R_L} \cdot 1 \geq 0.9$$

$$\frac{g_m (100)}{1 + g_m (100)} \geq 0.9$$

$$100 g_m \leq 0.9 + 90 g_m$$

$$10 g_m \leq 0.9$$

$$g_m \geq 0.09 \ \ S$$

$$g_m \geq 90 \ \ mS$$

BJT g_m

$$V_{be} \leq 0.2 V_T$$

$$V_{in} = V_{be} + V_{out}$$

$$V_{in} = V_{be} + i_e R_L$$

$$V_{in} = V_{be} + g_m V_{be} R_L$$

$$V_{in} = V_{be}(1 + g_m R_L)$$

$$V_{in} = 0.2 V_T (1 + g_m R_L)$$

$$0.5 = 0.2(0.025)(1 + g_m R_L)$$

$$100 = 1 + g_m R_L$$

$$99 = g_m R_L$$

$$99 = 100 g_m$$

$$g_m = 0.99 \ \ S$$

R_{in}

$$A_v = \frac{g_m R_L}{1 + g_m R_L} \cdot \frac{R_{in}}{R_t + R_{in}}$$

$$\frac{g_m R_L}{1 + g_m R_L} \cdot \frac{R_{in}}{R_t + R_{in}} \geq A_v$$

$$\frac{g_m R_L}{1 + g_m R_L} \cdot \frac{R_{in}}{R_t + R_{in}} \geq 0.9$$

$$\frac{(0.99)(100)}{1 + (0.99)(100)} \cdot \frac{R_{in}}{100 + R_{in}} \geq 0.9$$

$$R_{in} \leq 90 + 0.9 R_{in}$$

$$0.1 R_{in} \leq 90$$

$$R_{in} \geq 900\Omega$$

R_{eq}

Assume $\beta = 100$ and $\alpha = 1$

$$R_{in} = R_{eq} \parallel (\beta + 1)(r_e + R_L)$$

$$R_{in} = R_{eq} \parallel (\beta + 1)\left(\frac{\alpha}{g_m} + R_L\right)$$

$$R_{in} = R_{eq} \parallel (100 + 1)\left(\frac{1}{0.99} + 100\right)$$

$$R_{in} = R_{eq} \parallel (101)(1.01 + 100)$$

$$R_{in} = R_{eq} \parallel 10202.01$$

$$0.9k = R_{eq} \parallel 10.2k$$

$$0.9k = \frac{R_{eq} \times 10.2k}{R_{eq} + 10.2k}$$

$$0.9 R_{eq} + 9.18 = 10.2 R_{eq}$$

$$9.18 = 9.3 R_{eq}$$

$$R_{eq} = 987\Omega$$

CALCULATIONS

$R_1 + R_2$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_1 = 3.4k\Omega$$

$$R_2 = 1.85k\Omega$$

$$R_{eq} = R_1 \parallel R_2$$

$$R_{eq} = 1198\Omega$$

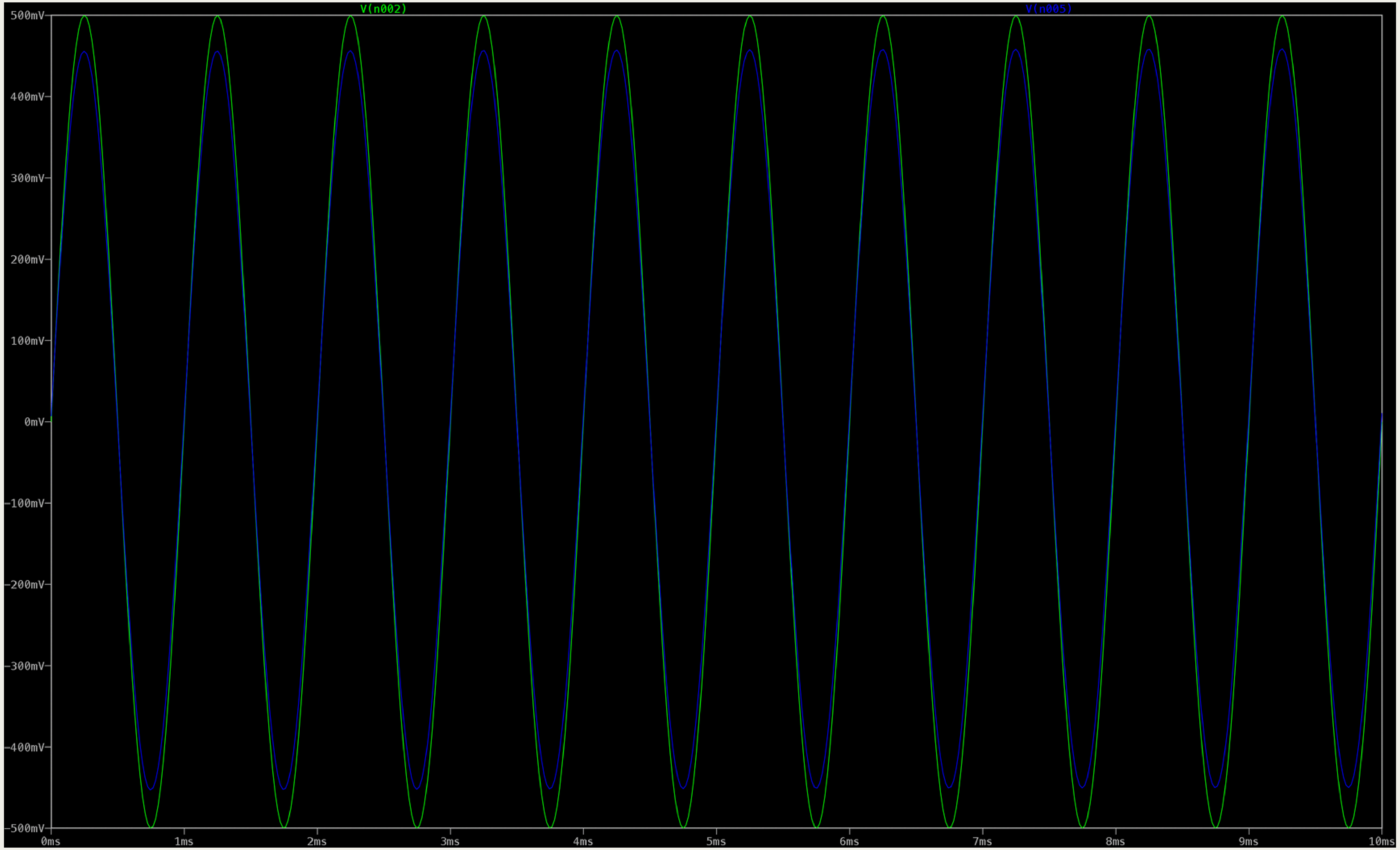
Check Gain

$$A_v = \frac{g_m R_L}{1 + g_m R_L} \cdot \frac{R_{in}}{R_t + R_{in}}$$

$$A_v = \frac{(0.99)(100)}{1 + (0.99)(100)} \cdot \frac{1198}{100 + 1198}$$

$$A_v = 0.914 \qquad \geq 0.9$$

3. SIMULATIONS



LTSpice

CALCULATIONS DETERMINED FROM SIMULATION

Overall Gain

$$Gain = \frac{V_{out}}{V_{in}}$$

$$Gain = \frac{0.455 - (-0.455)}{0.5 - (-0.5)}$$

$$Gain = \frac{0.91}{1}$$

$$Gain = 0.91$$

Input Resistance

$$R_{in} = \frac{V_{in}}{I_{in}}$$

$$R_{in} = \frac{0.5}{430\mu}$$

$$R_{in} = 1162.79\Omega$$

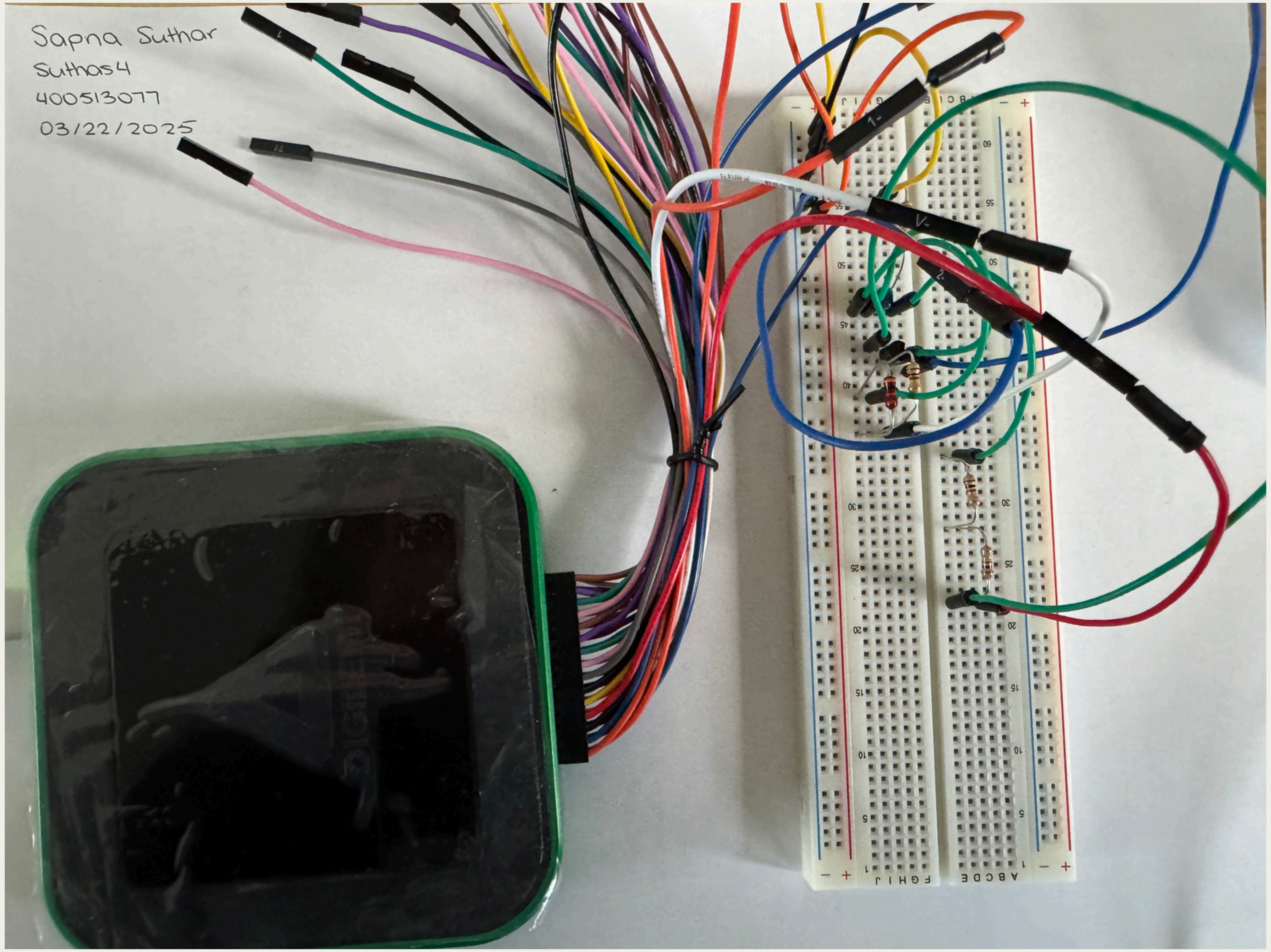
Attenuation

$$Attenuation = (1 - Gain) \times 100$$

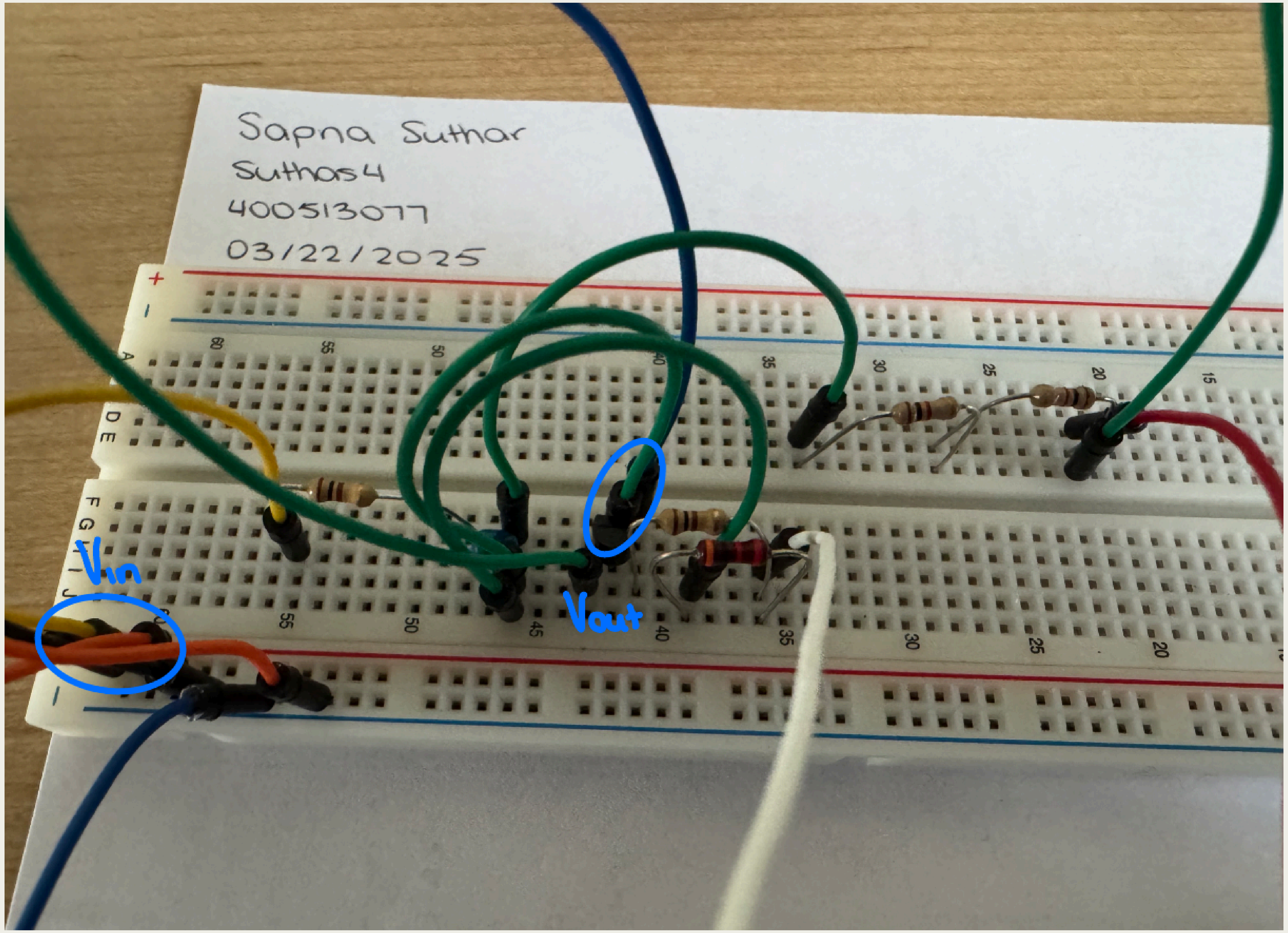
$$Attenuation = (1 - 0.91) \times 100$$

$$Attenuation = 9\%$$

4. PHYSICAL CIRCUIT



4. PHYSICAL CIRCUIT



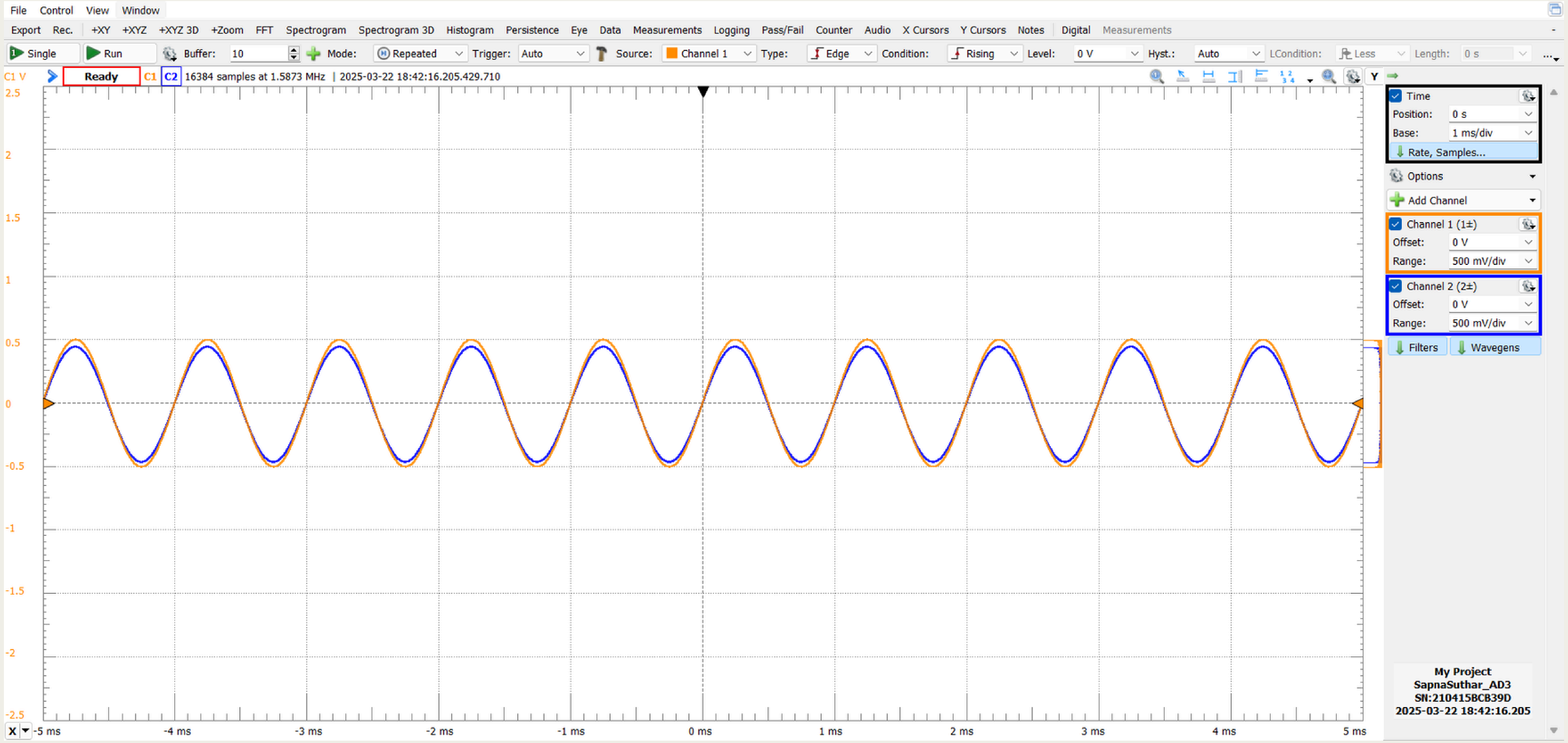
V_{in} = Wavegen (yellow wire)

V_{in} **probe** = orange wire

V_{out} **probe** = blue wire

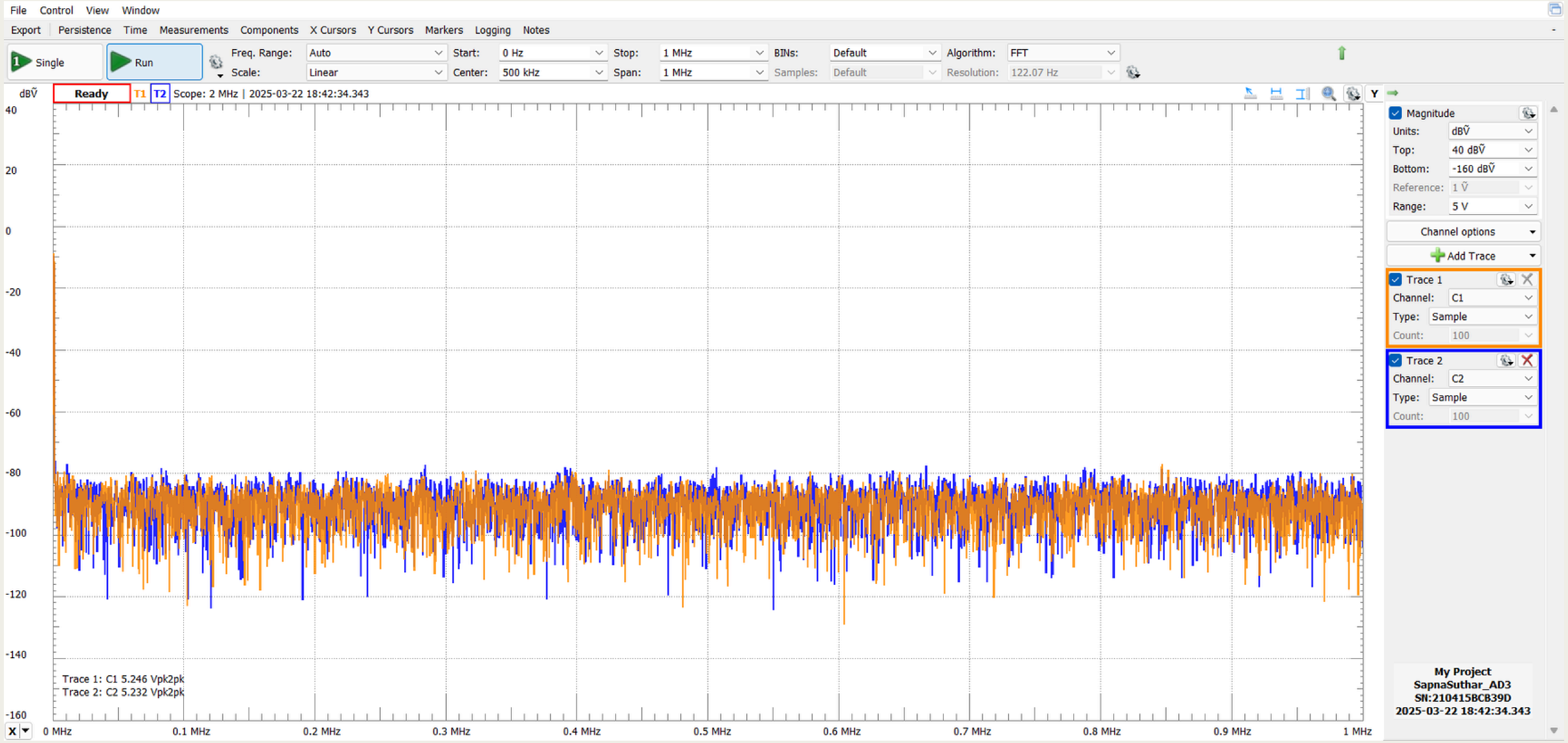
5. WAVEFORMS MEASUREMENTS

Input & Output Voltage vx. Time



5. WAVEFORMS MEASUREMENTS

Spectrum Graph to prove linearity



CALCULATIONS DETERMINED FROM SIMULATION

Waveform Gain

$$Gain = \frac{V_{out}}{V_{in}}$$

$$Gain = \frac{0.45 - (-0.45)}{0.5 - (-0.5)}$$

$$Gain = \frac{0.90}{1}$$

$$Gain = 0.90$$

Spectrum Gain

$$A_v = \frac{V_{out}}{V_{in}}$$

$$A_v = \frac{0.5232}{0.5246}$$

$$A_v = 0.9973$$

REFERENCES

[1] A. S. Sedra, K. C. Smith, T. C. Carusone, and V. Gaudet, Microelectronic circuits, 8th ed. New York, NY: Oxford University Press, 2019.

[2] “2N3904 TRANSISTOR (NPN),” Digikey, https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/6284/LUMIMAX2N5401.PDF (accessed Mar. 22, 2025).